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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1256

EFFECT OF 40° SWEEPBACK ON THE SPIN AND RECOVERY CHARACTERISTICS OF A $\frac{1}{25}$-SCALE MODEL OF A TYPICAL FIGHTER-TYPE AIRPLANE AS DETERMINED BY FREE-SPINNING-TUNNEL TESTS

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EFFECT OF 40° SWEEPBACK ON THE SPIN AND RECOVERY CHARACTERISTICS OF A $\frac{1}{25}$-SCALE MODEL OF A TYPICAL FIGHTER-TYPE AIRPLANE AS DETERMINED BY FREE-SPINNING-TUNNEL TESTS

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SUMMARY

Free-spinning-tunnel tests have been performed with a model of a typical fighter-type airplane to determine the effect of 40° sweepback on the spin and recovery characteristics. The spin and recovery characteristics of the model for both a swept-wing and an unswept-wing configuration were obtained for a range of typical-fighter loading conditions and for two tail designs. The investigation included tests of two wing-tip shapes on the swept-back wing.

The results of the tests indicated that for the model with a tail design considered unsatisfactory as regards spin recovery, sweeping the wings back 40° improved the recovery characteristics appreciably. With a revised tail design considered satisfactory as regards spin recovery for the unswept wing, sweeping the wings back 40° had little effect. The recovery characteristics of the model with the swept-back wing were essentially the same for either of the two wing-tip shapes tested.

INTRODUCTION

Because of the general interest in swept-back wings for high-speed aircraft an investigation has been conducted in the Langley 20-foot free-spinning tunnel to determine the effects on the spin and recovery characteristics of sweeping the wings back 40° on a $\frac{1}{25}$-scale model of a typical fighter-type airplane. The model used for the investigation had been previously tested with unswept wings in the Langley 20-foot free-spinning tunnel, and poor recovery characteristics for the original tail configuration were indicated. Satisfactory recovery characteristics were obtained, however, for a revised tail configuration (horizontal tail raised 12.5 inches and moved forward 20 inches, full-scale values). In the present tests both the original and the revised tail configurations were investigated over a wide range of mass distribution for both the swept and the unswept wing. Two wing-tip shapes were investigated on the swept-back wing.

SYMBOLS

b wing span, feet

S wing area, square feet

$\bar{c}$ mean aerodynamic chord, feet

$x/\bar{c}$ ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord

$z/\bar{c}$ ratio of vertical distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below fuselage reference line)

m mass of airplane, slugs

I_X, I_Y, I_Z moments of inertia about X-, Y-, and Z-axes (body), respectively, slug-feet^2

$\frac{I_X - I_Y}{mb^2}$ inertia yawing-moment parameter

$\frac{I_Y - I_Z}{mb^2}$ inertia rolling-moment parameter

$\frac{I_Z - I_X}{mb^2}$ inertia pitching-moment parameter

ρ air density, slug per cubic foot

μ airplane relative-density coefficient $\left(\frac{m}{\rho Sb}\right)$

α angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), degrees

ϕ angle between span axis and horizontal, degrees

V full-scale true rate of descent, feet per second

Ω full-scale angular velocity about spin axis, revolutions per second

σ helix angle, angle between flight path and vertical, degrees (For the present tests, the average absolute value of the helix angle was approx. 2.5°.)

APPARATUS AND METHODS

Model

The $\frac{1}{25}$-scale model used in the present spin tests was ballasted with lead weights to represent a typical fighter-type airplane at an altitude of 15,000 feet (ρ = 0.001496 slug per cubic foot). A three-view drawing of the model with the original tail installed, which shows the 0° swept-back and 40° swept-back wings used in the tests, as well as the respective locations of the wings on the fuselage, is shown in figure 1. The plan forms of the two wing-tip shapes tested on the 40° swept-back wing are indicated in figure 1.

When the wings were swept back 40° from their original unswept configuration, each wing was pivoted about the 50-percent point of the root chord. The dihedral and incidence were kept constant. The overlapping area rearward of the pivot point was cut away, whereas area forward of the pivot point was added by extending the leading edges until they intersected the fuselage. The total wing area was thus kept constant. The swept-back wings were moved forward on the fuselage so that the 30-percent point of the mean aerodynamic chord was at the same longitudinal position on the fuselage as was the 30-percent point of the mean aerodynamic chord of the unswept wings.

Photographs of the model with the 0° swept-back wing and with the 40° swept-back wing are shown in figure 2. The model with the 40° swept-back wing is shown spinning in the Langley 20-foot free-spinning tunnel in figure 3. A sketch showing the two tail configurations tested on the model is shown in figure 4.

A remote-control mechanism was installed in the model to actuate the rudder for recovery tests. Sufficient hinge moments were applied to the rudder to move it fully and rapidly to the desired positions.

Wind Tunnel and Testing Technique

The tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is, in general, similar to that described in reference 1 for the Langley 15-foot free-spinning tunnel except that the model-launching technique has been changed. With the controls set in the desired position, the model is launched by hand with spinning rotation into the vertically rising air stream. After a number of turns in the established spin, the recovery attempt is made by moving one or more controls by means of the remote-control mechanism. After recovery, the model dives into a safety net. The model spin data obtained are converted by methods described in reference 1 to represent values of the corresponding full-scale airplane.

In accordance with standard spin-tunnel procedure, tests were performed to determine the spin and recovery characteristics of the model for the normal spinning control configuration (elevator full up, ailerons neutral, and rudder full with the spin) and for various other aileron-elevator combinations including neutral and maximum settings of the control surfaces. Recovery was generally attempted by rapid reversal of the rudder from full with to full against the spin. Tests were also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. Such deviations are often inadvertently encountered in spinning airplanes and are simulated in model tests in order to define more completely the spin and recovery characteristics of a given design. Accordingly, tests were made on the present model with the elevator set at two-thirds of its full-up deflection and the ailerons set either at one-third of full deflection with the spin (stick right in a right spin) or one-third of full deflection against the spin. Recoveries from spins obtained at these two control configurations were attempted by rapidly reversing the rudder from full with to only two-thirds against the spin; the configuration that gave the slower recoveries is referred to as the "criterion spin." Spin-tunnel experience has resulted in the requirement that for a model to be considered satisfactory with regards spin recovery, the model must recover from the criterion spin in $2\frac{1}{4}$ turns or less.

Turns for recovery are measured from the time the controls are moved to the time the spin rotation ceases. For recovery attempts in which the model struck the safety net before recovery could be effected because of the wandering motion of the model, or because of an unusually high rate of descent, the number of turns from the time the controls were moved to the time the model struck the safety net were recorded. This number indicated that the model required more turns to recover from the spin than are shown, for example, greater than 3 (>3). A recovery requiring more than 3 turns, however, does not necessarily indicate an improvement when compared with a recovery requiring more than 7 turns. From certain spins with very high rates of descent, recovery attempts were made before the model had lost all the rotational energy imparted to it when launched in the air stream. Such recovery data are noted in the charts as "recovery attempted before model reached its final steeper attitude." Recovery results so obtained are considered conservative; that is, the recoveries are somewhat slower than those that would have been obtained had the model been at its final steeper spin attitude.

Sideslip at the center of gravity of the airplane in the spin may be determined from a consideration of the angles ϕ and σ. The inner wing (right wing in a right spin) must be down by an amount greater than the helix angle for the sideslip to be inward.

PRECISION

The spin results presented herein are believed to be the true values given by the model within the following limits:

α, degrees	± 1
ϕ, degrees	± 1
V, percent	± 5
Ω, percent	± 3

Turns for recovery:

Obtained from motion-picture records	$\pm\frac{1}{4}$
Obtained by visual estimate	$\pm\frac{1}{2}$

The preceding limits may have been exceeded for certain spins in which it was difficult to control the model in the tunnel because of the high rate of vertical descent or because of the wandering nature of the spin.

Spin-tunnel experience indicates that spin-tunnel-model results are not always in complete agreement with spin results of corresponding airplanes. In general, the models spin at a steeper angle of attack, at a somewhat higher rate of descent, and with 5° to 10° more outward sideslip than do the airplanes. For a representative group of models tested in the Langley 20-foot free-spinning tunnel, it was possible to predict satisfactorily the corresponding airplane recovery characteristics of about 80 percent of the models. For about 10 percent of the models tested the recovery results were conservative, and for 10 percent of the models the results were somewhat optimistic.

The accuracy of measuring the weight and mass distribution of the model are believed to be within the following limits:

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

The controls were set with an accuracy of ±1°.

TEST CONDITIONS

Spin tests of the model were performed for the conditions listed in table I. In order to cover a wide range of mass distribution, tests were made in which an appreciable amount of the mass along the wings was moved in toward the fuselage, in addition to tests made at the basic loading for which the distribution of mass was relatively heavy along the wings. The mass parameters for the loadings tested on the model and the corresponding full-scale mass characteristics are given in table II. The basic loading corresponds to the basic loading used in the original test program of the model.

When the wings of the model were swept back, the model was reballasted to obtain values of weight, center-of-gravity location, and moments of inertia approximately the same as those for the model with the unswept wing. The decrease in wing span associated with sweeping the wings back resulted in a change in aspect ratio from 5.51 to 3.80. As can be noted in table II, the nondimensional mass parameters also varied somewhat because of the change in wing span. In order to compensate for the increase in the negative value of the inertia yawing-moment parameter associated with sweeping the wings back 40°, tests were also made with mass extended along the wings. These tests were made with the revised tail installed.

Table III lists values of tail-damping power factors for the original-tail configuration and for the revised-tail configuration in which the horizontal tail was raised 12.5 inches and moved forward 20 inches (full scale); these tail-damping power factors, which give an indication of the effectiveness of the tail design in effecting recoveries, were computed by the method described in reference 2.

Full-scale dimensional characteristics of the airplane represented are given in table IV. The inertia parameters for the loadings tested have been plotted in figure 5, which may be used as an aid in predicting the relative effects of controls on the spin and recovery characteristics of the model (reference 3).

The maximum control deflections used in the tests were as follows:

Rudder, degrees	
Right	28
Left	28
Elevator, degrees	
Up	30
Down	20
Ailerons, degrees	
Up	13
Down	13

Intermediate control deflections used were as follows:

Rudder deflected 2/3 against, degrees	$18\frac{2}{3}$ left
Elevator deflected 2/3 up, degrees	20 up
Ailerons 1/3 deflected, degrees	
Up	$4\frac{1}{3}$
Down	$4\frac{1}{3}$

RESULTS AND DISCUSSION

The results of the tests are presented in charts 1 to 8. Because right and left spins and recoveries therefrom were found to be similar, only the results of the right spins are presented. The model data are presented in terms of full-scale airplane values at an altitude of 15,000 feet. When the wings were swept back, the associated change in wing span led to corresponding changes in aspect ratio, tail-damping power factor, relative density, and inertia parameters. Proper evaluation of the effects of the changes in each of these nondimensional parameters can not at present be made.

With the original tail installed on the model, there was an appreciable favorable effect on spin recoveries of sweeping the wings back 40°. Results are presented for the basic loading in chart 1 for the unswept wing and in chart 2 for the swept-back wing.

For the swept-back-wing configuration the spins were generally steeper; and although recoveries were not considered completely satisfactory, they were nevertheless much faster than for the configuration with unswept wings. In general, the largest effects were obtained for the elevator-up and aileron-with spins.

The favorable effect of sweeping the wings back was also obtained for the loading with I_X and I_Z decreased 50 percent of I_X, as can be seen by a comparison of results in charts 3 and 4. For this loading, however, the favorable effect of sweeping the wings back 40° was not so pronounced, the favorable effect being obtained generally only for elevator-up spins. Aileron-with settings led to very steep spins and rapid recoveries for both wing configurations, as might be expected for a loading for which the mass is distributed heavily along the fuselage (reference 3).

With the revised tail installed on the model, there were no appreciable effects on the spin or recovery of sweeping the wing back 40°. A comparison of charts 5 and 6 indicates satisfactory recovery characteristics for both the unswept wing and for the 40° swept-back wing for the basic-loading condition.

Results of tests made with I_X and I_Z decreased 50 percent of I_X with the revised tail and with the wings swept back 40° (chart 7) were generally similar to those obtained for the corresponding configuration when the model was in its basic loading. There was, however, a more pronounced aileron effect, particularly when the elevator was neutral or down. Aileron-with settings generally led to steep spins and fast recoveries, whereas aileron-against settings led to flatter spins and slow recoveries.

Results of tests made with I_X and I_Z increased 20 percent of I_X with the revised tail installed and the wings swept back 40° are presented in chart 8 and are generally similar to those obtained for the corresponding tests at the basic loading.

The effect of changing the tip shape on the swept-back wing was investigated with the revised tail installed on the model for the basic loading; for these tests, wing tips 1 (see fig. 1) were installed on the model. Results of the tests indicated little effect on the spin and recovery characteristics and, therefore, are not presented in chart form.

CONCLUDING REMARKS

The following concluding remarks are based on the results of free-spinning-tunnel tests of a model of a typical fighter-type airplane with 0° and with 40° sweepback in the wings:

1. Sweeping the wings back 40° on the model with a tail design considered unsatisfactory as regards spin recovery improved the recovery characteristics appreciably.

2. Sweeping the wings back 40° on the model with a tail design considered satisfactory as regards spin recovery had little effect on the recovery characteristics.

3. The recovery characteristics of the model with the swept-back wing were essentially the same for either of the two wing-tip shapes tested.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., January 2, 1947

REFERENCES

1. Zimmerman, C. H.: Preliminary Tests in the N.A.C.A. Free-Spinning Wind Tunnel. NACA Rep. No. 557, 1936.

2. Neihouse, Anshal I., Lichtenstein, Jacob H., and Pepoon, Philip W.: Tail-Design Requirements for Satisfactory Spin Recovery. NACA TN No. 1045, 1946.

3. Neihouse, A. I.: A Mass-Distribution Criterion for Predicting the Effect of Control Manipulation on the Recovery from a Spin. NACA ARR, Aug. 1942.

TABLE I.- CONDITIONS OF MODEL INVESTIGATED IN THE

LANGLEY 20-FOOT FREE-SPINNING TUNNEL

[Flaps and landing gear retracted; right erect spins]

Tail configuration	Loading		Angle of sweep-back of wing (deg)	Wing tips installed on 40° swept-back wing (fig. 1)	Data in chart
	Designation	Description			
Original	1_0	Basic loading with 0° swept-back wing	0	----------	1
Do----------	1_{40}	Basic loading with 40° swept-back wing	40	Tip 2	2
Do----------	2_0	I_X and I_Z decreased by 50 percent of I_X for basic loading with 0° swept-back wing	0	----------	3
Do----------	2_{40}	I_X and I_Z decreased by 50 percent of I_X for basic loading with 40° swept-back wing	40	Tip 2	4
Horizontal tail raised 12.5 inches and moved forward 20 inches (full-scale values)	1_0	Basic loading with 0° swept-back wing	0	----------	5
Do----------	1_{40}	Basic loading with 40° swept-back wing	40	Tip 2	6
Do----------	2_{40}	I_X and I_Z decreased by 50 percent of I_X for basic loading with 40° swept-back wing	40	Tip 2	7
Do----------	3_{40}	I_X and I_Z increased by 20 percent of I_X for basic loading with 40° swept-back wing	40	Tip 2	8
Do----------	1_{40}	Basic loading with 40° swept-back wing	40	Tip 1	-----

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TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS TESTED ON MODEL

[Model values are presented in terms of full-scale values]

Loading		Weight (lb)	μ at sea level	μ at 15,000 ft	Center-of-gravity location		Moments of inertia about center of gravity			Inertia parameters		
Designation	Description				$x/\bar{c}$	$z/\bar{c}$	I_X (slug-ft^2)	I_Y (slug-ft^2)	I_Z (slug-ft^2)	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
1_0	Basic for 0° swept-back wing	16,396	15.6	24.9	0.300	0.070	16,335	18,011	33,519	-18×10^{-4}	-168×10^{-4}	186×10^{-4}
1_{40}	Basic for 40° swept-back wing	16,613	19.24	30.58	.299	.070	15,941	18,938	32,557	-47	-216	263
2_0	I_X and I_Z decreased 50 percent of I_X for basic loading with 0° swept-back wing	16,685	15.9	25.3	.321	.060	7,962	20,956	27,337	-139	-68	207
2_{40}	I_X and I_Z decreased 50 percent of I_X for basic loading with 40° swept-back wing	16,674	19.31	30.69	.308	.070	7,853	21,106	26,519	-209	-85	294
3_{40}	I_X and I_Z increased 20 percent of I_X for basic loading with 40° swept-back wing	16,478	19.09	30.33	.283	.070	19,100	19,809	36,584	-11	-268	279

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TABLE III.- TAIL-DAMPING POWER FACTORS

FOR CONDITIONS TESTED ON MODEL

Wing	Tail configuration	Tail-damping ratio	Unshielded rudder volume coefficient	Tail-damping power factor
0° sweepback	Original	0.0190	0.00759	144×10^{-6}
Do-----	Horizontal tail raised 12.5 inches and moved forward 20 inches	.0460	.02120	979
40° sweepback	Original	.0280	.00920	257
Do-----	Horizontal tail raised 12.5 inches and moved forward 20 inches	.0680	.0257	1750

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TABLE IV.- DIMENSIONAL CHARACTERISTICS OF TYPICAL FIGHTER-TYPE AIRPLANE REPRESENTED IN MODEL TESTS

	0° swept-back wing	40° swept-back wing
Wing:		
Span, ft	42.5	35.0
Area, sq ft	322.2	322.2
Incidence	Wing reference plane parallel to thrust line at root	Wing reference plane parallel to thrust line at root
Aspect ratio	5.51	3.8
Dihedral of wing, deg	6	6
Mean aerodynamic chord, in.	92.4	117.4
Leading edge of mean aerodynamic chord rearward of leading edge of root chord, in.	6.46	85.65
Ailerons:		
Inboard chord rearward of hinge line, percent of wing chord	14.07	14.07
Outboard chord rearward of hinge line, percent of wing chord	19.40	19.40
Area rearward of hinge line, percent of wing area	8.62	8.62
Span, percent of wing span	39.4	39.4
Horizontal tail surfaces:		
Total area, sq ft	55.0	55.0
Span, ft	16.0	16.0
Total elevator area, sq ft	22.0	22.0
Distance from center of gravity (for basic loading) to elevator hinge line, ft	22.5	22.5
Vertical tail surfaces:		
Total area, sq ft	25.8	25.8
Total rudder area, sq ft	11.9	11.9
Distance from center of gravity (for basic loading) to rudder hinge line, ft	22.7	22.7
Over-all length, ft	36.1	36.1

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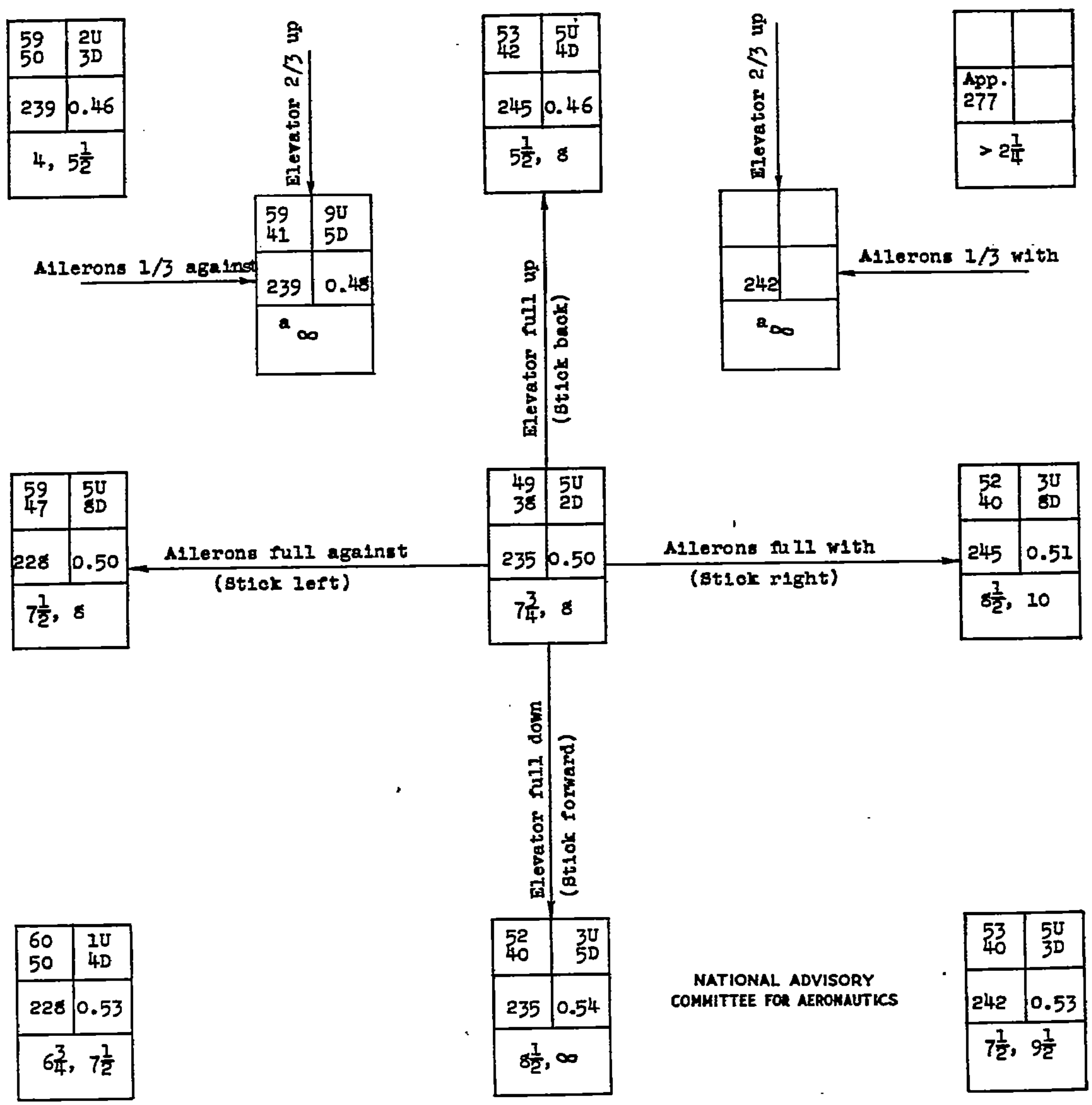
CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL WITH 0° SWEPT-BACK WING AND ORIGINAL TAIL

[Basic loading for 0° swept-back wing (loading point 1_0 in table II and fig. 5); recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



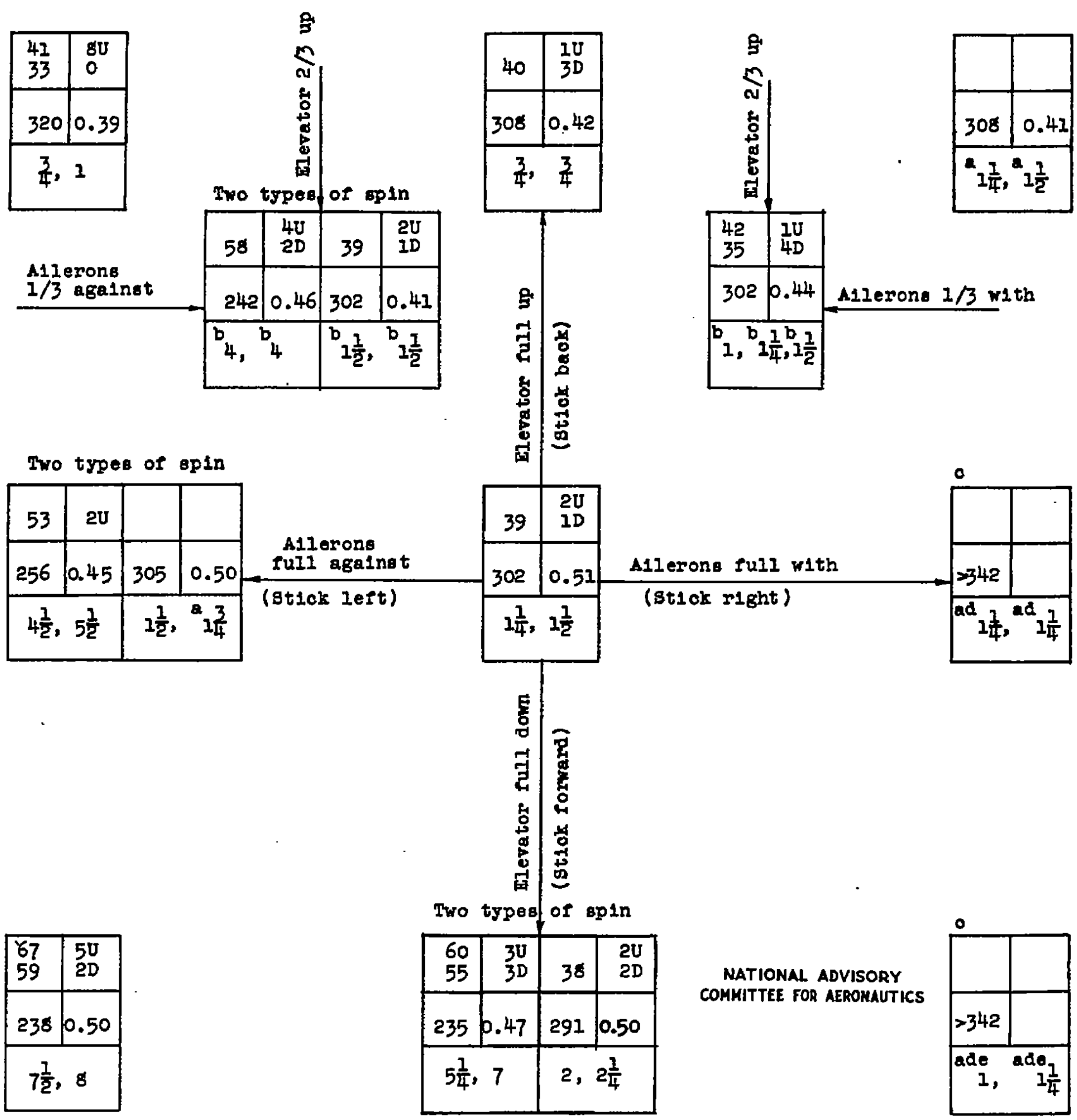
[a]Recovery attempted by rapid reversal of rudder from full with to 2/3 against the spin.

Average or range of model values given; converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL WITH 40° SWEPT-BACK WING, WING TIPS 2 INSTALLED, AND ORIGINAL TAIL

[Basic loading for 40° swept-back wing (loading point 1_{40} in table II and fig. 5); recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



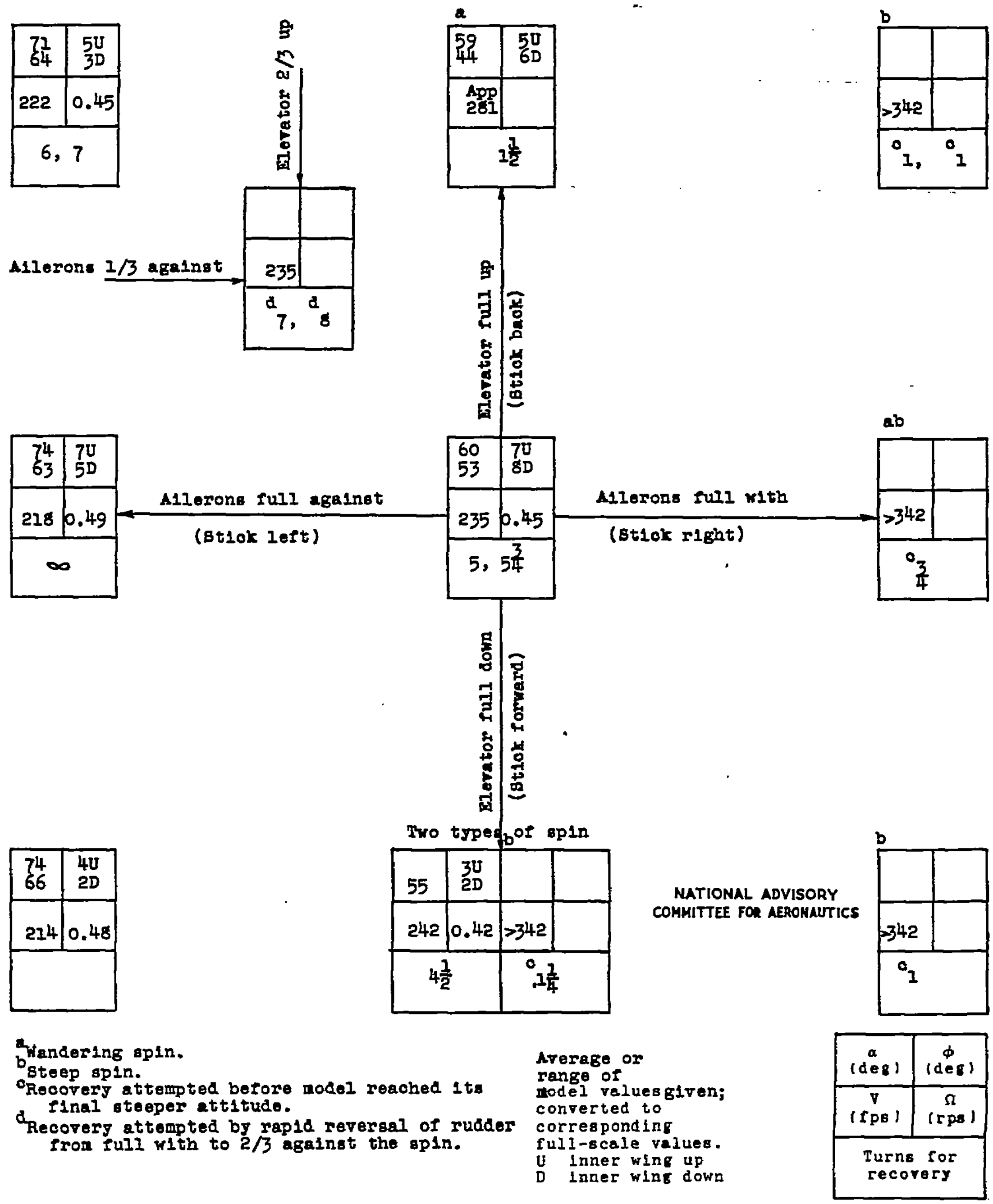
[a]Visual estimate.
[b]Recovery attempted by rapid reversal of rudder from full with to 2/3 against the spin.
[c]Steep spin.
[d]Recovery attempted before model reached its final steeper attitude.
[e]Model recovers in inverted attitude.

Average or range of model values given; converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 3.- SPIN AND-RECOVERY CHARACTERISTICS OF MODEL WITH 0° SWEPT-BACK WING, ORIGINAL TAIL, AND RELATIVE MASS DISTRIBUTION DECREASED ALONG WINGS

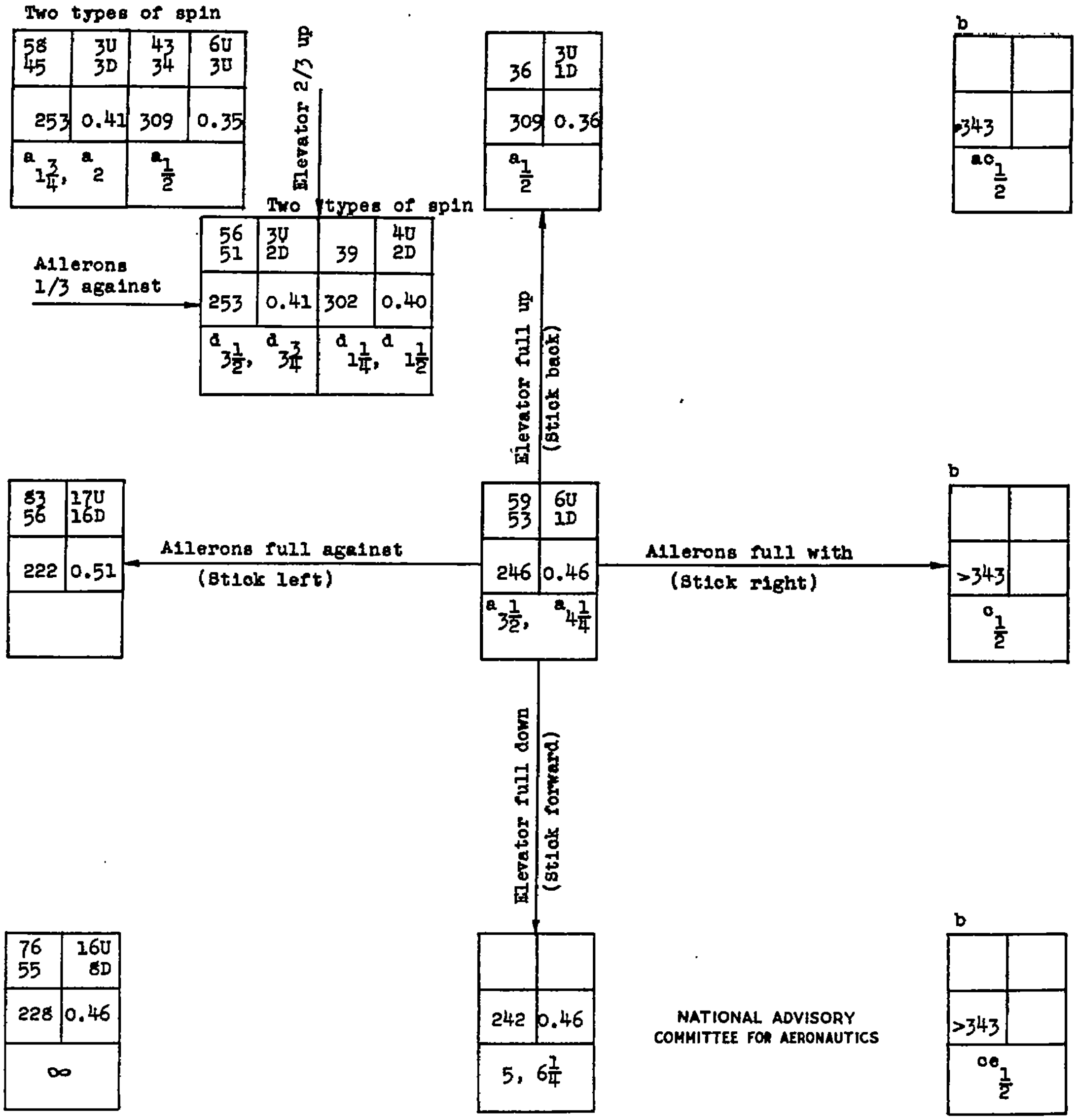
[I_X and I_Z decreased 50 percent of I_X with 0° swept-back wing (loading point 2_0 in table II and fig. 5); recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



[a]Wandering spin.
[b]Steep spin.
[c]Recovery attempted before model reached its final steeper attitude.
[d]Recovery attempted by rapid reversal of rudder from full with to 2/3 against the spin.

CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL WITH 40° SWEPT-BACK WING, WING TIPS 2 INSTALLED, ORIGINAL TAIL, AND RELATIVE MASS DISTRIBUTION DECREASED ALONG WINGS

[I_X and I_Z decreased 50 percent of I_X with 40° swept-back wing (loading point 2_{40} in table II and fig. 5); recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



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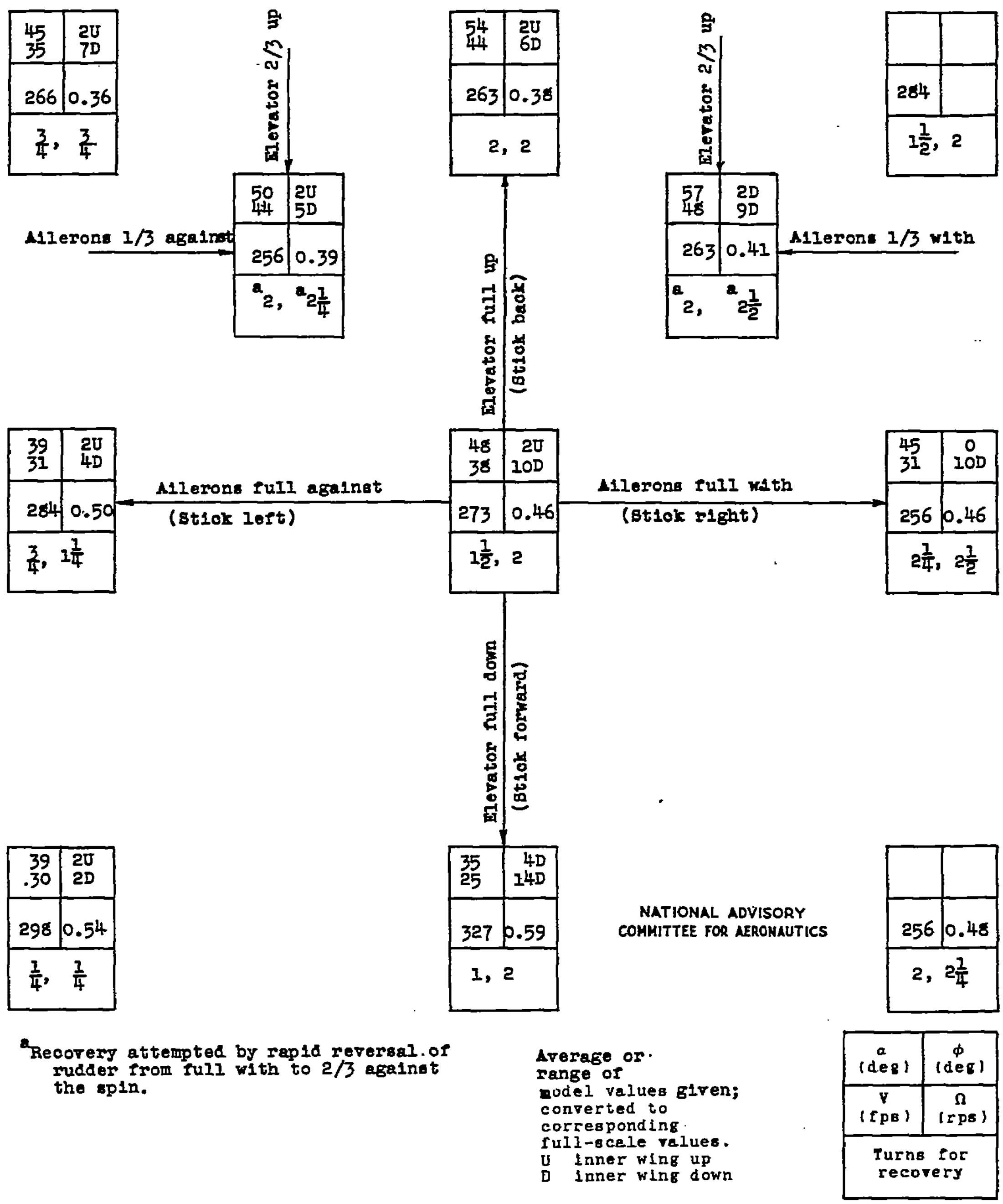
[a]Visual estimate.
[b]Steep spin.
[c]Recovery attempted before model reached its final steeper attitude.
[d]Recovery attempted by rapid reversal of rudder from full with to 2/3 against the spin.
[e]Model recovers in inverted attitude.

Average or range of model values given; converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 5.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL WITH 0° SWEPT-BACK WING AND REVISED TAIL

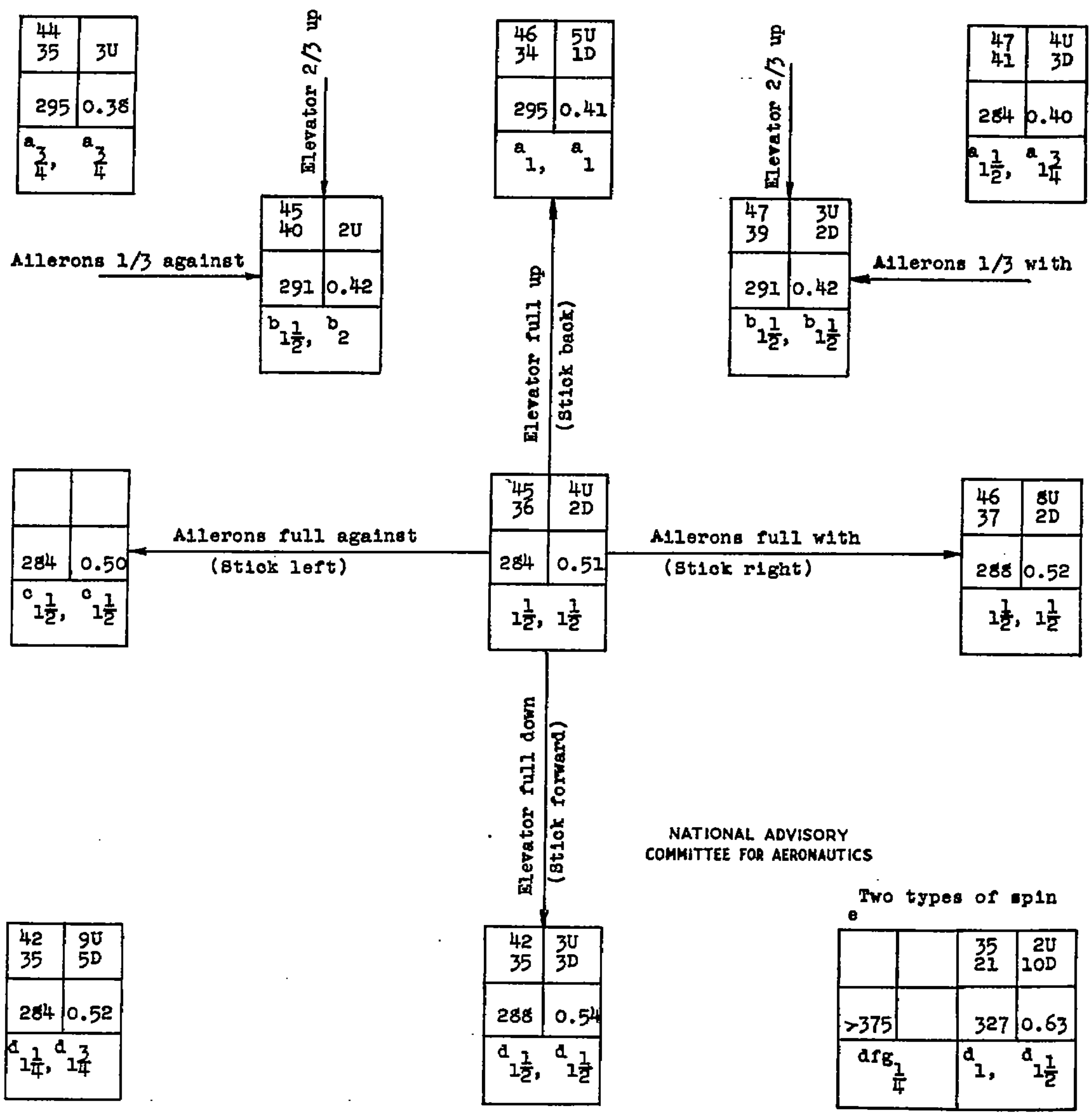
[Basic loading for 0° swept-back wing (loading point 1_0 in table II and fig. 5); recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



[a]Recovery attempted by rapid reversal of rudder from full with to 2/3 against the spin.

CHART 6.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL WITH 40° SWEPT-BACK WING, WING TIPS 2 INSTALLED, AND REVISED TAIL

[Basic loading for 40° swept-back wing (loading point 1_{40} in table II and fig. 5); recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



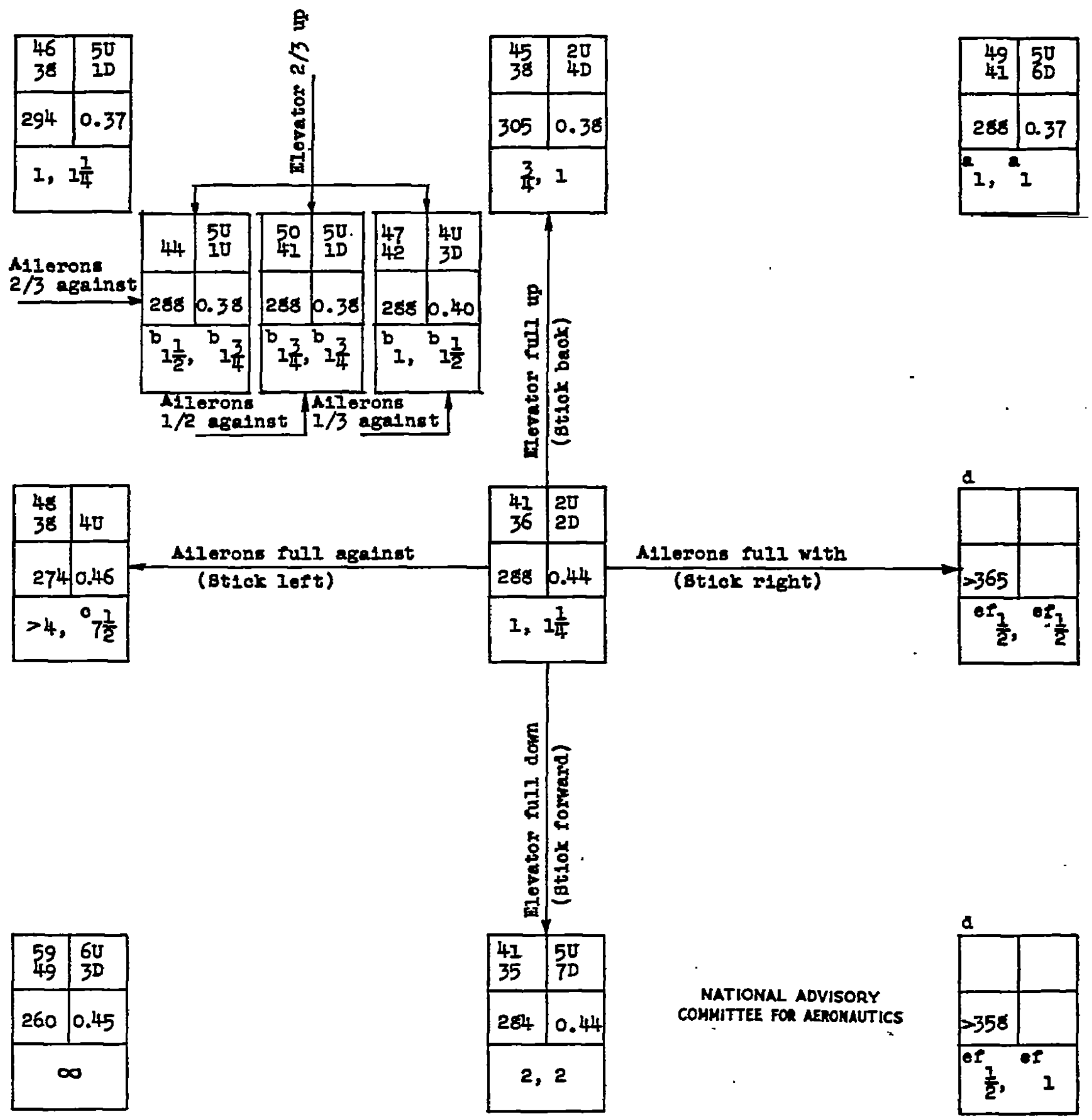
[a]Recovers in erect dive.
[b]Recovery attempted by rapid rudder reversal from full with to 2/3 against the spin.
[c]Model recovers in a steep dive.
[d]Model recovers in inverted attitude.
[e]Steep spin.
[f]Recovery attempted before model reached its final steeper attitude.
[g]Visual estimate.

Average or range of model values given; converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 7.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL WITH 40° SWEPT-BACK WING, WING TIPS 2 INSTALLED, REVISED TAIL, AND RELATIVE MASS DISTRIBUTION DECREASED ALONG WINGS

[I_X and I_Z decreased 50 percent of I_X with 40° swept-back wing (loading point 2_{40} in table II and fig. 5); recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



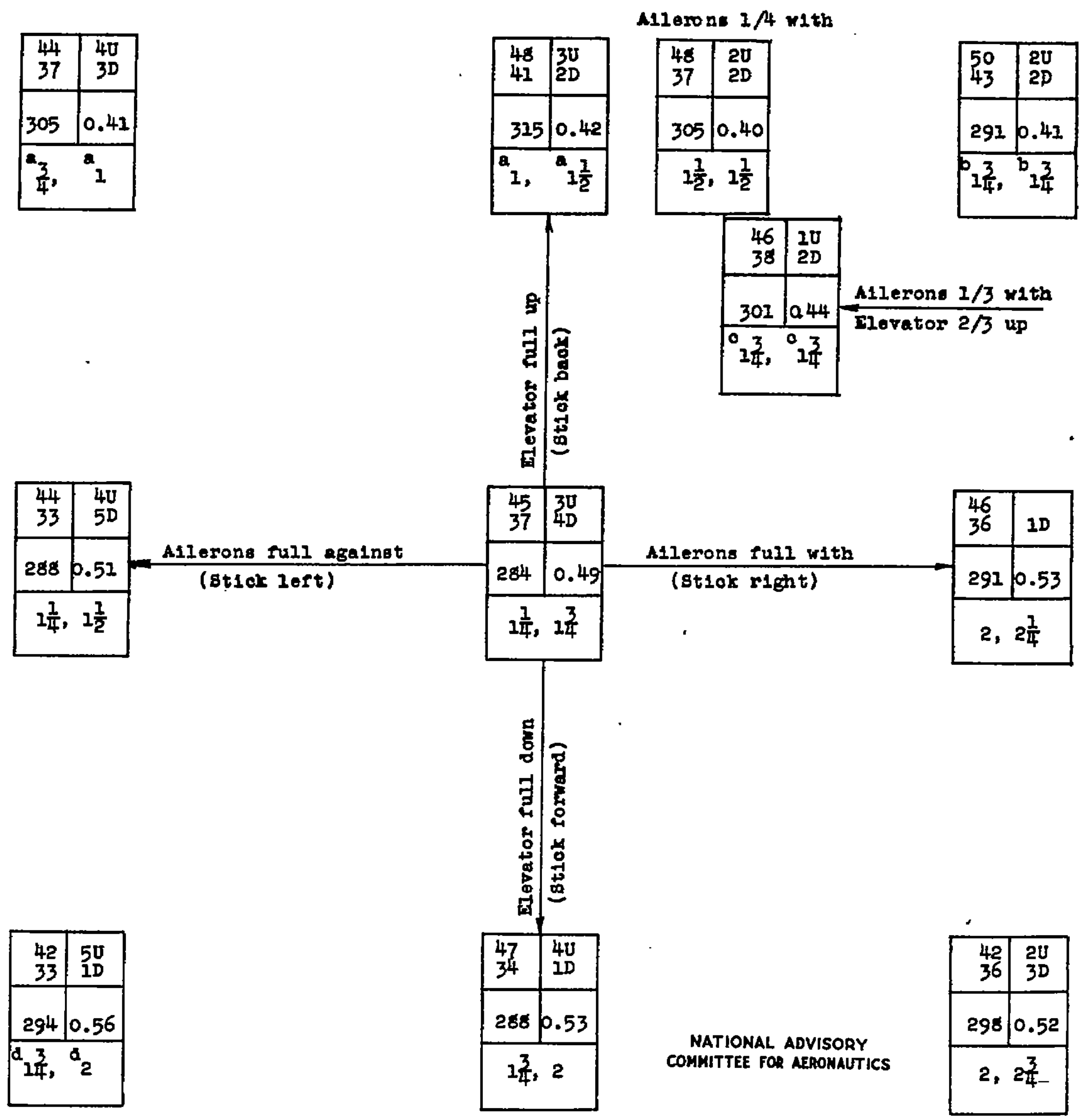
[a]Model recovers in a dive.
[b]Recovery attempted by rapid rudder reversal from full with to 2/3 against the spin.
[c]Visual estimate.
[d]Steep spin.
[e]Recovery attempted before model reached its final steeper attitude.
[f]Model recovers in inverted dive.

Average or range of model values given; converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 8.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL WITH 40° SWEPT-BACK WING, WING TIPS 2 INSTALLED, REVISED TAIL, AND RELATIVE MASS DISTRIBUTION INCREASED ALONG WINGS

[I_X and I_Z increased 20 percent of I_X with 40° swept-back wing (loading point 3_{40} in table II and fig. 5); recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



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[a]Recovers in erect dive.
[b]Model recovers in a wide radius spiralling dive.
[c]Recovery attempted by rapid rudder reversal from full with to 2/3 against the spin.
[d]Model recovers in inverted attitude.

Average or range of model values given; converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

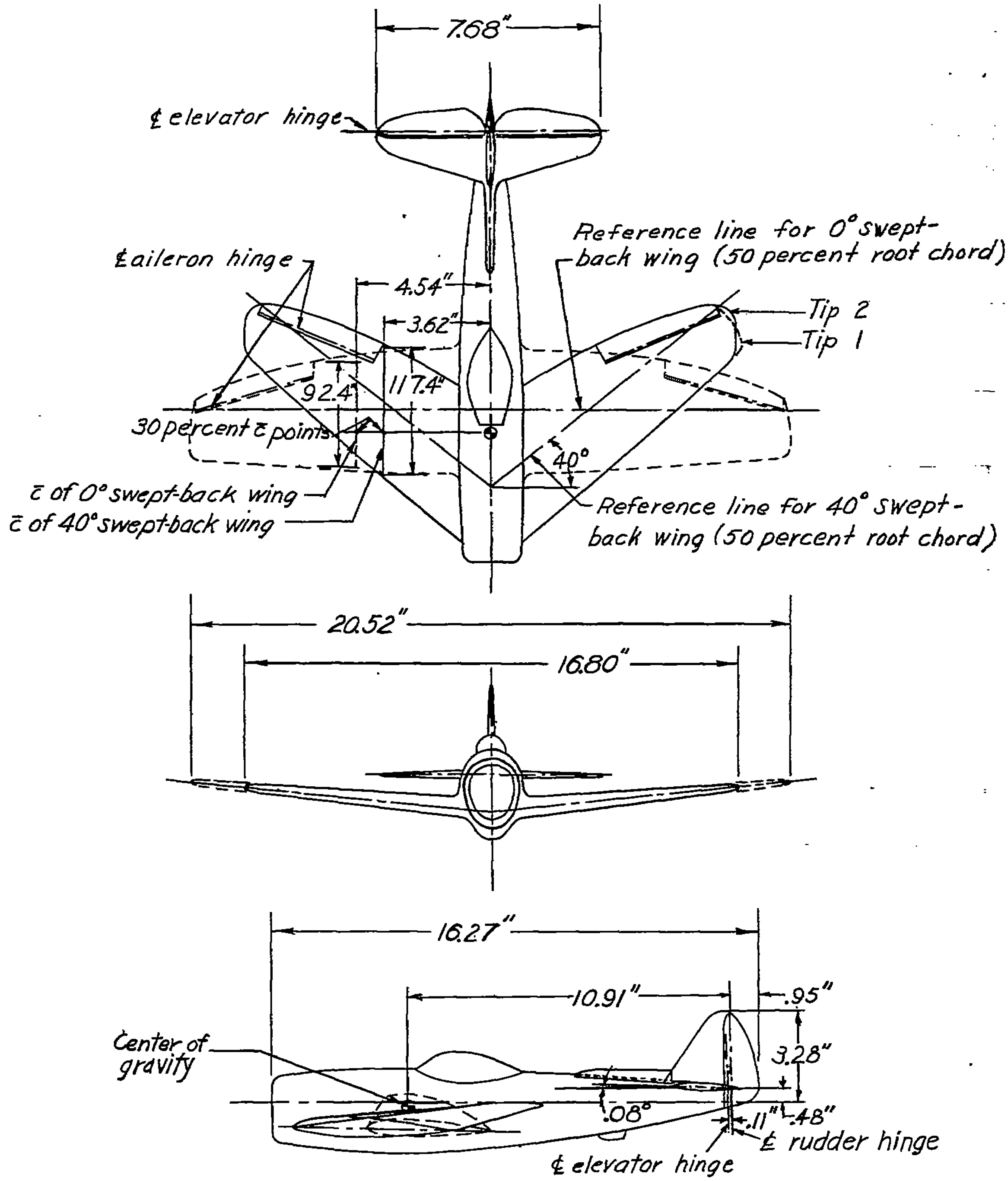

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Figure 1.- Three-view drawing of the $\frac{1}{25}$-scale model of a typical fighter-type airplane. Center of gravity is shown for the basic loading condition.

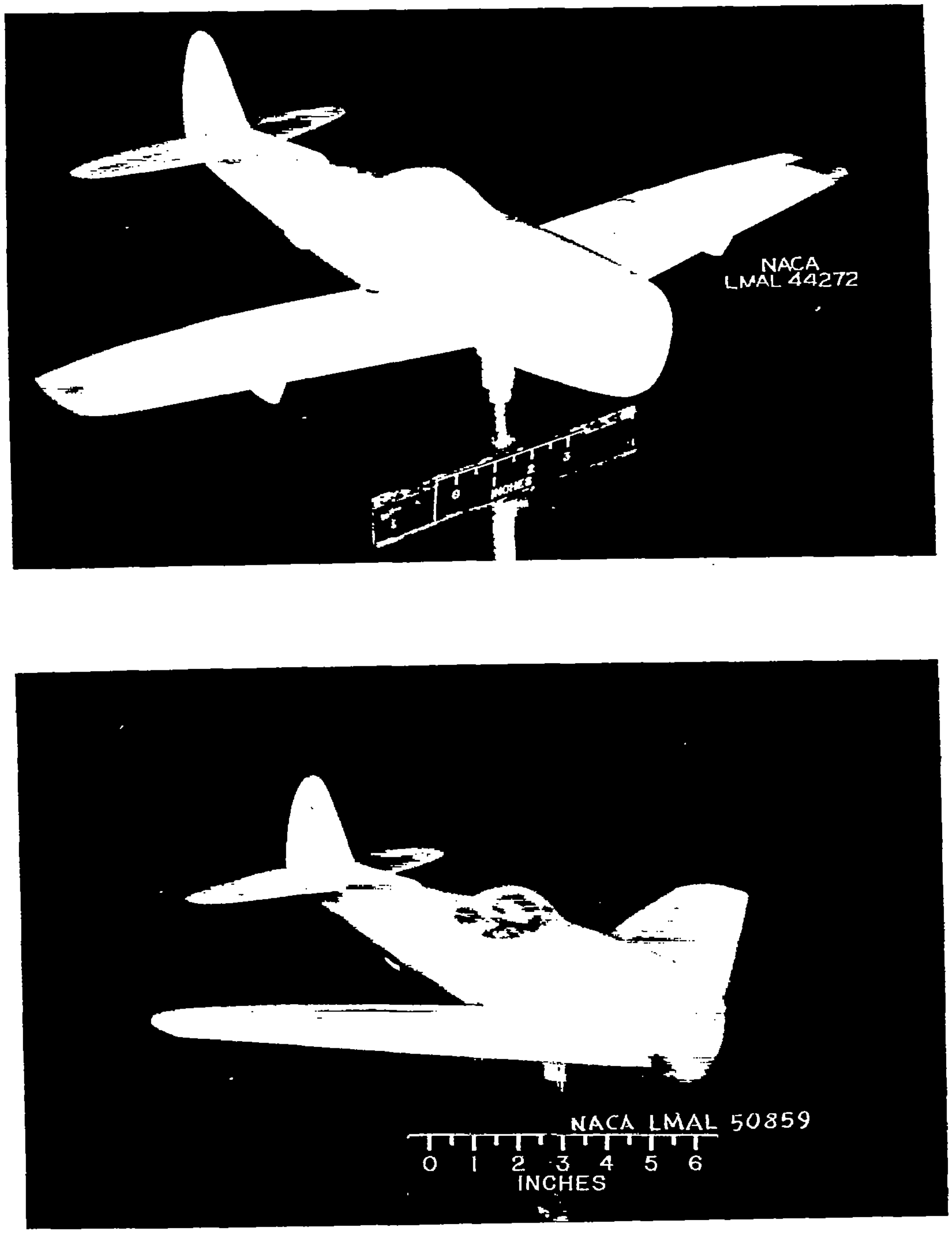

Figure 2.- Photographs of the model with the 0° swept-back wing (top) and of the model with the 40° swept-back wing (bottom).

Figure 3.- Photograph of the model with the 40° swept-back wing spinning in the Langley 20-foot free-spinning tunnel.

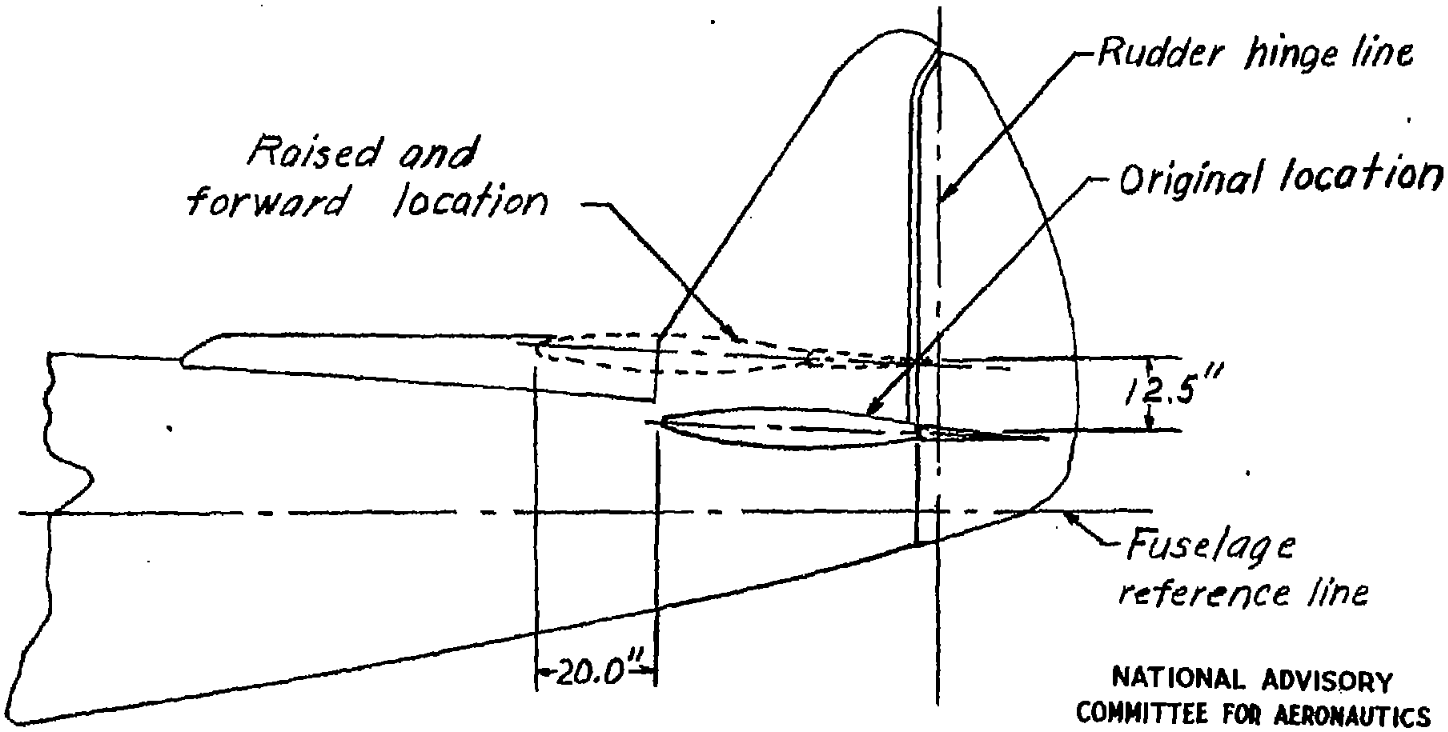

Figure 4.- Sketch showing the two locations of the horizontal tail tested on the model.(Dimensions are full scale.)

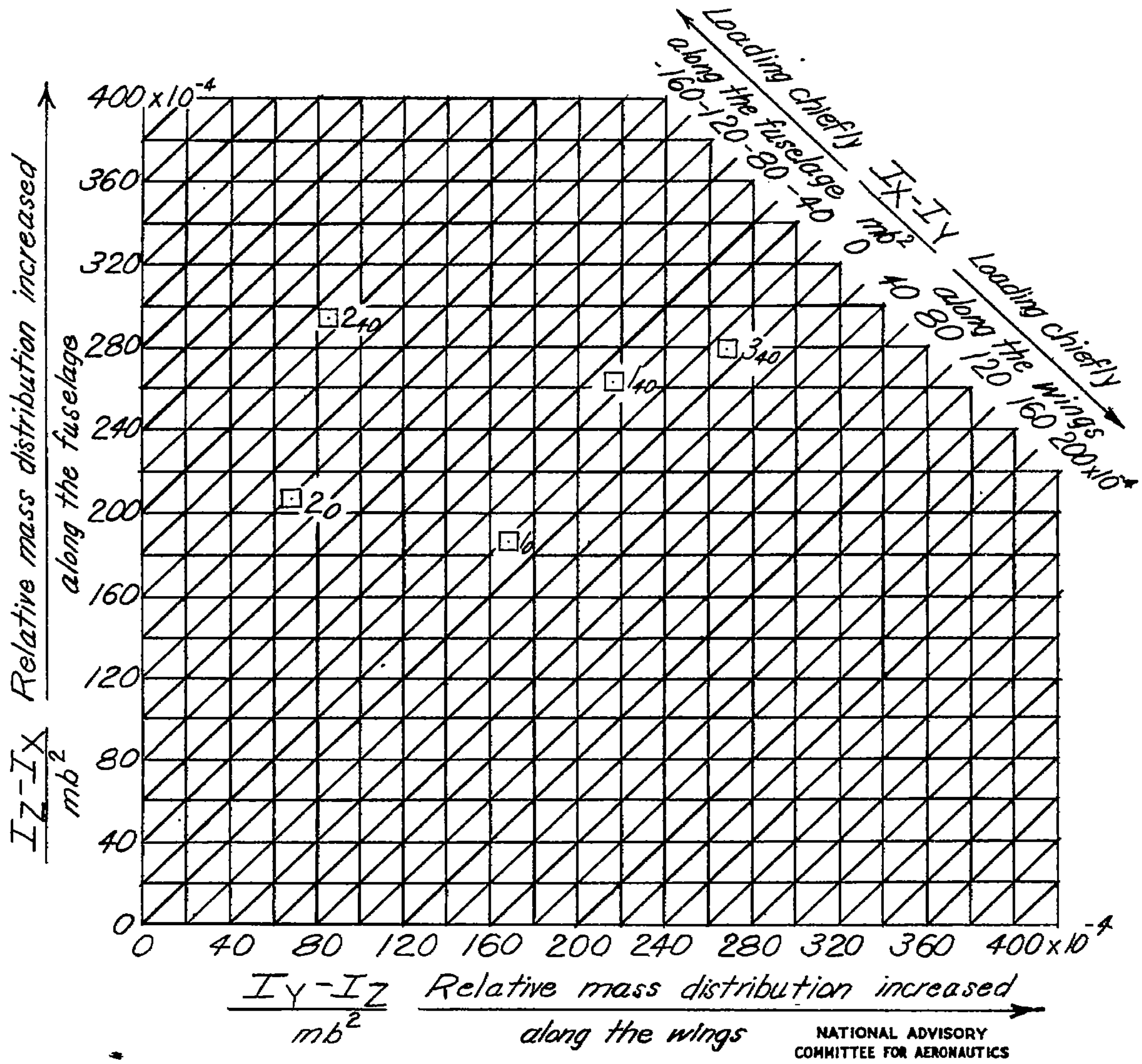

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Figure 5.- Inertia parameters for loadings tested on the model. (Points are for loadings listed in table II.)